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(54) **Ballistic armor**

(57) Ballistic armor for providing ballistic protection from an impacting projectile threat. The armor comprises a plurality of composite armor units. Each unit comprises a ceramic body having a cylindrical body portion with two end faces, one of which is adapted to face said threat. Each unit further comprises a non-ceramic belt member assembled with the ceramic body so that said member contiguously surrounds the cylindrical body portion without covering the one end face.

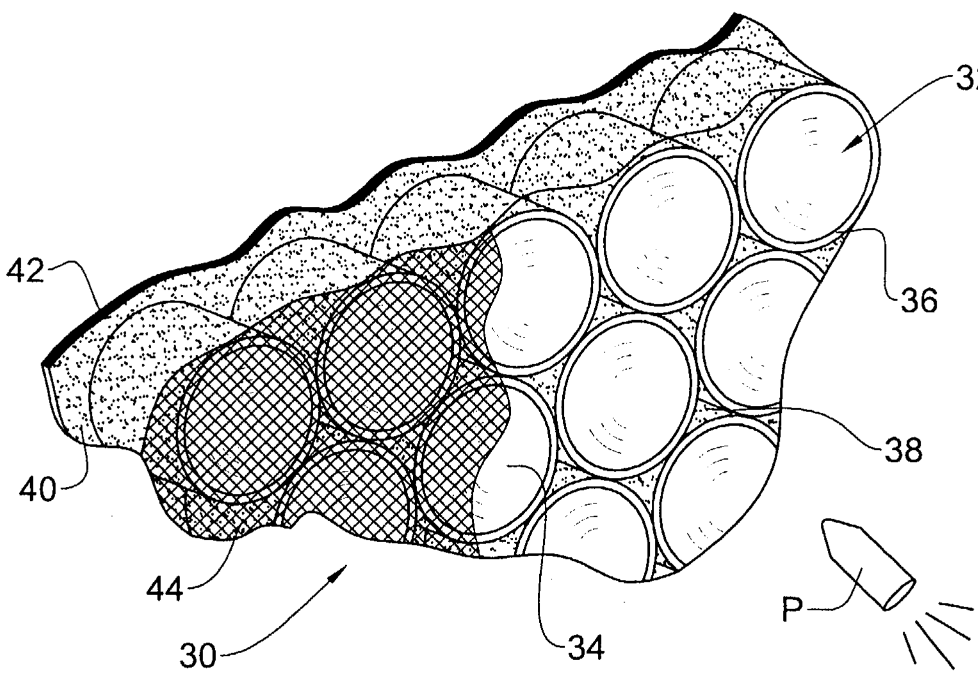

FIG. 1

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Description

[0001] This invention relates to ballistic armor and, in particular, to such armor comprising ceramic bodies.

[0002] It is known in the art to provide composite armor plates with a plurality of juxtaposed ceramic bodies such as tiles, cylinders, or spheres in order to protect against impacting ballistic threats.

[0003] US 3,616,115 discloses a composite armor plate comprising successive layers of small discrete ceramic blocks encapsulated within a metal matrix by solid-state diffusion bonding. The ceramic blocks are maintained under compression in order to increase the amount of energy required by an impacting projectile to shatter the blocks.

[0004] US 5,361,678 discloses composite armor comprising ceramic spheres embedded in a metal matrix. The spheres are fully coated with a binder and ceramic particles in order to insulate them from thermal shock waves produced by the molten matrix during the embedding stage, as well as to enhance the ballistic performance of the armor.

[0005] US 6,112,635 discloses a composite armor plate for absorbing and dissipating kinetic energy from a high velocity, armor-piercing projectile, the plate comprising a single layer of ceramic cylinders arranged in a plurality of adjacent rows. The cylinders are in direct contact with each other and are bound by a solidified material.

[0006] The present invention suggests ballistic armor for providing ballistic protection from an impacting projectile threat, the armor comprising a plurality of composite armor units, each comprising a ceramic body having a cylindrical body portion with two end faces, one of which is adapted to face said threat, and a non-ceramic belt member assembled with said ceramic body so that said member contiguously surrounds said cylindrical body portion without covering said one end face.

[0007] Preferably, each composite armor unit according to the present invention is bound to other such units by a binding material to form the armor. The armor preferably further comprises a backing layer as is known in the art for trapping fragments of the armor ejected by the impact of the projectile threat.

[0008] The cylindrical body portion of the ceramic body, from which the composite armor unit of the present invention is assembled, may have different cross-sectional shapes such as e.g. circular, polygonal, or the like.

[0009] The end faces of the ceramic body may be flat, and one may thereby constitute a base for the body portion. As additional examples, the end faces may be convex, bulging away from the body portion, or they may be concave, dipping into said portion. Various such designs may enhance the ballistic performance of the armor or yield other advantages. The two end faces may not necessarily be of the same design.

[0010] The ceramic body of the composite armor unit according to the present invention may be made of any known armor ceramic material, such as Alumina, Silicon Carbide, Silicon Nitride, Boron Carbide, or any other refractory material such as ceramic glass and the like. A ceramic material containing reinforcing fibers, as known in the art, may also be used.

[0011] The belt member, assembled with the ceramic body in accordance with present invention, has an outer perimeter, and an inner perimeter defining a hollow region to receive and adjoiningly surround the ceramic body to fit about its cylindrical portion. The inner perimeter of the belt member is designed to conform to the shape of said cylindrical body portion to enable the member to closely hug the body after assembly. The outer perimeter of the belt member may be of any design and its dimensions and/or shape may vary along the height of the belt member.

[0012] The belt member according to the present invention advantageously allows for a variety of possible shapes and sizes for its outer perimeter. For example, the outer perimeter of the belt member may be circular, elliptical, rectangular, otherwise polygonal, or may have an irregular shape but it is preferable that it have a simple geometry to facilitate its manufacture. Such possibilities allow the composite armor unit and the ballistic armor of the present invention to be suited to a wide range of needs. For example, the belt member may have a hexagonal outer perimeter to allow the unit with which it is assembled to be contiguous with neighboring units in the armor, thereby eliminating the interstices between the units and increasing ballistic immunity to smaller projectile threats. As another example, in order to reduce weight of the unit, and therefore the armor, the belt member may have recesses, such as holes or depressions, formed therein or may have a thickness which varies along its height. In addition, the belt member may not necessarily extend along the entire height of the cylindrical body portion of the ceramic body with which it is assembled, but rather may, for example, have a ring-like shape to simply adjoin the perimeter of the body at a certain height. The above two design possibilities may both be embodied together in the belt member when in the form of a spiral, for example. The spiral belt member may extend along the majority of the ceramic body with which it is assembled, with a space separating successive turns of the spiral. In this way, the spiral design of the belt member serves to reduce the weight of the unit without sacrificing its ballistic performance.

[0013] The belt member of the present invention may be made of a variety of materials so long as the belt member possesses a minimal amount of tensile strength, which is at least about 3 kg/mm^2. Possible materials include but are not limited to metal alloys such as Aluminum, Titanium and Steel alloys, composites such as glass, carbon and aramids, Kevlar™, high strength plastics such as Nylon, polycarbonates, and polyamids, High Density Poly-Ethylene (HDPE) within various resins, carbon fibers and the like. The various resins may include simple fabric, winded fabrics, or mats reinforcement resins.

[0014] Calculations that will be presented below show that one of the main advantages provided by ballistic armor comprising composite armor units according to the present invention, is a much desired geometrical weight reduction per unit area of armor. To maximize this advantage, the average density of the belt member should be less than that of the ceramic material from which the body is made. The average density of the belt member depends not only on the material from which it is made, but also on its design. Providing the belt member with depressions as mentioned above, for example, would serve to reduce its average density.

[0015] The geometrical weight reduction enabled by the present invention is achieved by providing each of the composite armor units, from which the armor is composed, with a belt member of such a design as to reduce each unit's average density without decreasing its ballistic effectiveness. Determination of the optimal design of the belt member may be made by computer calculation and simulation or by trial and error, bearing in mind the nature of the expected threat from which ballistic protection is desired, in particular the types, calibers, ranges, and inclinations of the impacting projectiles. In general, the most important parameter to consider in selecting such a design is the maximal thickness *t* of the belt member.

[0016] It is clear from the above that the maximal possible reduction in the average density of the composite armor unit and the ballistic armor of the present invention is dictated by the necessity to keep the ballistic performance of the armor at a high level so that it may protect against the expected impacting projectile threat. Indefinitely increasing the thickness *t* of the belt member will surely further reduce the weight of the armor but at some point, ballistic performance will also be compromised. It was found that both significant geometrical weight reduction is achieved and high ballistic performance is maintained so long as the thickness *t* of the belt member does not surpass about 10% of the ceramic body's diameter *D*.

[0017] The minimal reduction of the average density or weight of the body that would still be considered essential is limited by the need to justify the costs of manufacturing a belt member according to the present invention. Thus, while the provision of a belt member having a thickness of 0.01%, for example, of the diameter *D* of the ceramic body would also render the composite armor unit lighter to some minor extent, this would not constitute an essential reduction in the unit's average density as it is not sufficiently beneficial to justify such a belt member's manufacture. In general, a belt member having a thickness *t* of at least about 1% of the diameter D would be considered an essential reduction.

[0018] The composite armor unit of the present invention employed in ballistic armor provides additional advantages, which increase the armor's ballistic effectiveness. Firstly, the belt member of the present invention confines the cylindrical body on which it is mounted so that upon a projectile's impact on the body, the member radially resists and delays ceramic fracture of the body outwardly towards the member's perimeter and also applies resistance forces, which prevent penetration of the projectile. In addition, the belt member provides separation between the cylindrical bodies, which along with the radial confinement it affords, prevents one body's ceramic fracture due to projectile impact from affecting neighboring bodies. In order to enhance these two advantages, the belt member may be assembled with the body so as to hug the body tightly providing it with inward radial compression, thereby increasing resistance. Both of the above advantages increase the armor's multi-hit capability, allowing it to withstand a plurality of projectile impacts while maintaining high ballistic performance. In certain circumstances, the latter advantages may be crucial to the point of being preferable over a reduction in weight, in which case heavier materials may be used to form the belt members in order to enhance ballistic performance at the expense of geometrical weight gain.

[0019] The ballistic armor of the present invention is preferably assembled from a single layer of composite armor units, but may also be formed from a plurality thereof. The composite armor units may or may not be in direct contact with each other. The ballistic armor is preferably in the form of a plate and may be curved to allow it to conform to various surfaces whose ballistic protection is desired. The binding material used to hold the units together may be any known suitable material such as thermoset plastic (e.g. epoxy resin or polyurethane) and thermoplastic material (e.g. polyester, polycarbonate, polyamid). The backing layer of the ballistic armor in accordance with the present invention serves to trap ceramic fragments as well as the residual deformed projectile or fragments thereof, resulting from its impact and penetration. The backing layer may be made of any suitable material known in the art, e.g. aluminum, woven or unidirectional fabric laminates comprising Spectra®, Dyneema®, Kevlar™, Twaron™, S_2 or E glass fibers, HDPE, aramids and the like within various resins. The armor preferably also includes a cover material, such as a frontal spall cover, to cover and seal the front of the armor and to keep the units in place, as well as to minimize outward deflection of the impacting projectile threat, fragments of the threat or the units resulting from impact and/or other frontal debris. The cover material is preferably made from layers of fibers, such as Kevlar™ and fiberglass, saturated within thermoplastic and thermoset resins.

[0020] The ballistic armor according to the present invention may further include an intermediate layer, as known in the art, between the composite armor units of the present invention and the backing layer to provide a stand-off distance, enhancing the ballistic effectiveness of the armor. Such an intermediate layer may have any design, such as a cellular honeycomb arrangement, and may be made of any appropriate substance, such as foamed materials. Other components known in the art to be used in composite ballistic armor technology may also be added to the armor of the present invention.

[0021] In order to understand the invention and to see how it may be carried out in practice, a preferred embodiment will now be described, by way of non-limiting example only, with reference to the accompanying drawings, which are not necessarily drawn to scale and are provided merely for the purpose of illustration, include:

Fig. 1 is ballistic armor according to the present invention;
Fig. 2A is a ceramic cylinder used in composite armor technology as known in the art;
Fig. 2B is a cross-section of an armor plate as known in the art comprising ceramic cylinders of the kind shown in Fig. 2A;
Fig. 3A is a composite armor unit according to the present invention;
Fig. 3B is a cross-section of a piece of ballistic armor shown in Fig. 1 according to the present invention;
Fig. 4A is another embodiment of the composite armor unit in accordance with the present invention;
Fig. 4B is a cross section of the composite armor unit shown in Fig. 4A;
Fig. 4C is yet another embodiment of the composite armor unit in accordance with the present invention;
Fig. 4D is a cross section of the composite armor unit shown in Fig. 4C;
Fig. 4E is yet another embodiment of the composite armor unit in accordance with the present invention;
Fig. 4F is a cross section of the composite armor unit shown in Fig. 4E;
Fig. 4G is yet another embodiment of the composite armor unit in accordance with the present invention;
Fig. 4H is a cross section of the composite armor unit shown in Fig. 4G.

[0022] Fig. 1 shows a section of a ballistic armor 30 according to the present invention for providing protection from an impacting projectile threat P. The armor 30 comprises a plurality of composite armor units 32 according to the present invention arranged in a single layer of parallel rows. Each unit 32 is assembled from a cylindrical ceramic body 34 having one flat end face and one convex end face adapted to face the threat P, and from a belt member 36 mounted thereon in accordance with the present invention. The belt member 36 is a thin-walled tube whose circular inner and outer perimeters conform to the shape of the cylindrical ceramic body 34. Each belt member 36 contiguously surrounds one cylindrical ceramic body 34 to form one unit 32. The units 32 are in direct contact with each other forming interstices 38 therebetween. The units 32 are bound together by a binding material 40, which occupies the interstices 38, as well as the periphery of the armor 30. The armor 30 further includes a backing layer 42 covering the flat end faces of the bodies 34 on the rear side. On its front side, the armor 30 includes a spall cover 44 covering the convex end faces of the bodies 34 and sealing the units 32 in place.

[0023] The cylindrical ceramic bodies 34 are made by standard methods of ceramic manufacturing known in the art. The belt member 36 is produced in different ways corresponding to the material from which it is made. For example, for alloys of Aluminum, Steel, or Titanium, any known metallic production methods, such as extrusion, may be employed. For belt members 36 made of fiberglass, Kevlar™, or carbon, for example, filament-winding manufacturing methods are used. In any case, the belt member 36 is made so that its inner diameter matches closely to the diameter *D* of the ceramic body 34 to allow it to be mounted thereon by simple sliding.

[0024] To assemble the composite armor unit 32 according to the present invention, a single belt member 36 is mounted onto one ceramic body 34 by hand or by machine.

[0025] The geometrical weight reduction achieved by the assembly of the belt member 36 in the composite armor unit 32 according to the present invention can be best understood by comparing composite armor as known in the prior art with ballistic armor 30 in accordance with the present invention.

[0026] Fig. 2A shows a typical, known ceramic cylinder 2 with a circular cross-section and one convex end face 4 adapted to face an impacting projectile threat. Fig. 2B is a cross-section of a piece of composite armor plate 6 comprising three ceramic cylinders 2 as shown in Fig. 2A, each cylinder 2 having a diameter *D* and being arranged in close contact as is known in the art and creating interstitial spaces 8 between them. The cylinders 2 are typically held in place by resins (not shown) occupying the spaces 8 and are covered by layers of ballistic fabric (not shown). Since they typically contain material lighter than ceramic, the interstitial spaces 8 serve to decrease the weight of the plate 6 whilst being small enough not to reduce its ballistic performance.

[0027] A first imaginary equilateral triangle 10 may be considered by connecting the centers of the three cylinders 2 in Fig. 2B. The triangle 10 may be taken as a representative area for the entire plate according to which the ceramic cylinder's weight proportion η_0 may be calculated. Using the geometry of the triangle 10, it can be shown that:

$$\eta_0 = \frac{\pi}{2\sqrt{3}} = 0.906$$

Therefore, approximately 91% of the area of the plate 6 is occupied by ceramic material, which is the plate's heaviest and most abundant component. The interstitial spaces 8, which are fully or partially filled with resin, constitute the remaining 9% of the plate's area.

[0028] Fig. 3A shows the composite armor unit 32 according to the present invention assembled from the ceramic body 34, which is similar to the cylinder 2 shown in Fig. 2A. The ceramic body 34 also has a diameter D and includes the belt member 36 in accordance with the present invention mounted thereon. Fig. 3B is a cross-section of a piece 46 of the ballistic armor 30 shown in Fig. 1 comprising three composite armor units 32 as shown in Fig. 3A, the units 32 being arranged and bound similarly to the cylinders 2 in Fig. 2A. The belt members 36 have a thickness *t* and as a result each unit 32 has a diameter $D + 2t$, which is larger than that of cylinder 2. Consequently, interstice 38 is larger in area than interstitial space 8.

[0029] A second imaginary equilateral triangle 48, may be considered by connecting the centers of the three bodies 34 in Fig. 3B and may be taken as a representative area for the entire armor 30 according to which the armor unit's weight proportion η may be calculated. Using the geometry of the triangle 48, it can be shown that if *x* is a ratio between the thickness *t* of the belt member 36 and the diameter *D* of the body 34, namely $x = t/D$, then the armor unit's weight proportion η for belt members 36 of average density ρ_{bm} and ceramic bodies 34 of average density ρ_{cb} is

$$\eta = \frac{\pi}{2\sqrt{3}} \cdot \varphi$$

where the factor φ is given by:

$$\varphi = \frac{1 + 4x\left(\frac{\rho_{bm}}{\rho_{cb}}\right)}{(1 + 2x)\sqrt{1 + 4x}}$$

It is clear from the above that when $x = 0$ (i.e. when there is no belt member 36), then $\eta = \eta_0$.

[0030] The above calculations show that as long as the belt members 36 have a lower average density than the ceramic cylindrical bodies 34 (i.e. $\rho_{bm} < \rho_{cb}$), the factor φ will be a fraction and the armor unit's weight proportion η will be less than the ceramic cylinder's weight proportion η_0 (i.e. $\eta < \eta_0$). The latter, in addition to the enlarged area of interstice 38 in comparison with interstitial space 8, renders the weight per unit area of armor 30 lower than that of the plate 6.

[0031] The following table shows an example of possible extents of weight reduction as a function of the ratio *x* for ballistic armor comprising composite armor units according to the present invention assembled from a cylindrical body made from 98% Alumina (Al_2O_3) and having an average density of ρ_{cb} = 3.84 g/cm^3, with a belt member made from an Aluminum alloy and having an average density of ρ_{bm} = *2.75* g/cm^3 mounted thereon:

x	Φ	η	Approximate weight reduction
0.01	0.989	0.896	10%
0.02	0.978	0.886	11%
0.03	0.968	0.877	12%
0.04	0.958	0.868	13%
0.05	0.949	0.860	14%
0.06	0.940	0.851	15%
0.07	0.931	0.843	16%
0.08	0.922	0.836	16%
0.09	0.914	0.828	17%
0.1	0.906	0.821	18%

As can be seen above, for a ratio *x* of 0.1, a weight reduction per unit area of about 18% over the plate shown in Fig. 2B can be achieved without a significant decrease in ballistic performance.

[0032] For a given projectile threat P, the number, size, shape, and arrangement of the composite armor units 32 in the ballistic armor 30 of the present invention yielding the optimal ballistic performance may be selected by trial and error. In the present example, the following parameters have been used and results achieved for the units 32 arranged as shown in Fig. 1, for successfully and repeatedly protecting from the threat of 14.5 mm caliber API-B32 armor piercing bullets fired from an equivalent range of 250 meters, at an inclination of 0° (Nato) and having an impact velocity of 890 m/s):

Ceramic material of ceramic body - 98% Alumina (Al_2O_3)
Density (specific gravity) of ceramic material: 3.84 g/cm^3
Dimensions of cylindrical body: circular base of diameter D = 19 mm; height of 19 mm; convex spherical end faces having radii of curvature of R = 31 mm.
Material of belt member: Al 6063T6
Thickness of belt member: t = 0.7 mm

The armor plate in the form of an add-on module is bolted to a 7.3 HHS (MIL-A-46100D) surface, for which enhanced ballistic protection is desired. The plate includes a 10 mm Kevlar™ backing layer weighing 14 g/m^2. It was shown that an armor plate with the above parameters weighs 65 kg/m^2, in comparison to an identical competing plate (as in Fig. 2B) not employing the belt member of the present invention, which weighs 69 kg/m^2. This considerable 5.8% decrease in weight is achieved without any reduction in the plate's ballistic performance for the above threat as well as for other projectiles. In fact, the ballistic performance is improved by 10% as the multi-hit capability is found to yield a 90 mm spacing between shots, whereas the competing plate yields a 100 mm spacing between shots.

[0033] Clearly, various modifications within the scope of the composite armor unit and ballistic armor according to the present invention may be made. For example, Fig. 4A shows a composite armor unit 50 in accordance with present invention assembled from a cylindrical body 51 with two convex spherical end faces and a belt member 52 mounted thereon having a circular inner perimeter to tightly surround the body 51, and a hexagonal outer periphery. The belt member 52 includes depressions 53 formed therein to further reduce the average density of the member 52, and thereby the geometrical weight of the unit 50. A cross-section of the unit 50 is shown in Fig. 4B. In order to achieve extremely high ballistic performance, such hexagonal units may be used in ballistic armor to form a contiguous plate devoid of interstitial spaces. The depressions 53 aid to offset the gain in weight resulting from the absence of the interstitial spaces.

[0034] Fig. 4C shows yet another embodiment of the composite armor unit according to the present invention. The unit 60 is assembled from a substantially cylindrical body 61 having a hexagonal perimeter and two flat end faces. The belt member 62 mounted on the body 61 has a ring-like shape and does not extend along the entire height of the body 61, but rather contiguously surrounds only a central portion thereof. As can be seen in the cross-section of the unit 60 in Fig. 4D, the member 62 has both a hexagonal inner perimeter to conform to the body 61, and a hexagonal outer perimeter. The ring-like design for the belt member 62 serves to further reduce the geometrical weight of the unit 60, but also allows for ballistic armor devoid of interstitial spaces and therefore having high ballistic performance.

[0035] Fig. 4E shows yet another embodiment of the composite armor unit 70 according to the present invention. The unit 70 is assembled from a cylindrical body 71 having one flat end face as its base and one convex end face adapted to face the projectile threat. The belt member 72, which has a circular inner and outer perimeter, includes indentations 73 formed therein, as can be seen in a cross-section of the unit 70 shown in Fig. 4F. The indentations 73 serve to reduce the geometrical weight of the unit 70 without sacrificing ballistic performance. As is also shown in Fig. 4F, the belt member 72 is in the form of a cup within which the body 71 sits. The belt member 72 extends to cover the base of the body 71 and includes a through hole 74 on its underside below the base of the body 71. During assembly of the unit 70, the body 71 is placed into the cup-shaped belt member 72 and pressed down until its base contacts the bottom of the member 72. Since the belt member 72 contiguously surrounds the body 71, air occupying the cup-shaped belt member 72 cannot escape along its walls when the body 71 is placed therein, and therefore exits via the through hole 74 designed for this purpose.

[0036] Fig. 4G shows yet another embodiment of the composite armor unit 80 according to the present invention. The unit 80 is assembled from a cylindrical body 81 having one flat end face as its base and one convex end face adapted to face the projectile threat. The belt member 82, which has a circular inner and outer perimeter, is in the form of a spiral. The member 82 is mounted on the body 81 and extends along a majority of its height. As is also shown by the cross-section of the unit 80 in Fig. 4H, spaces 83 present between successive turns of the spiral belt member 82 serve to reduce the geometrical weight of the unit 80 without sacrificing ballistic performance.

[0037] It should be understood that the above described embodiments are only examples of composite armor units and ballistic armor comprising them in accordance with the present invention, and that the scope of the present invention fully encompasses other embodiments which may become obvious to those skilled in the art.

Claims

1. A composite armor unit for providing ballistic protection from an impacting projectile threat, the unit comprising a ceramic body having a cylindrical body portion with two end faces, one of which is adapted to face said threat, and a non-ceramic belt member assembled with said ceramic body so that said member contiguously surrounds said cylindrical body portion without covering said one end face.

2. A composite armor unit according to Claim 1, wherein the ceramic body and the belt member each has an average density such that the average density of said member is lower than that of said body.

3. A composite armor unit according to Claim 1, wherein the ceramic body is made from one of the following: Alumina, Silicon Carbide, Silicon Nitride, Boron Carbide, ceramic glass.

4. A composite armor unit according to any of the preceding Claims, wherein the belt member is made from a material having a tensile strength of at least 3 kg/mm^2.

5. A composite armor unit according to Claim 4, wherein said material is a metallic alloy.

6. A composite armor unit according to Claim 5, wherein said alloy includes one of the following: Aluminum, Titanium, Steel.

7. A composite armor unit according to any of Claims 1- 4, wherein the belt member is made from one of the following: glass, carbon, aramids, Kevlar™, Nylon, polycarbonates, polyamids, High Density Poly-Ethylene, carbon fibers.

8. A composite armor unit according to any of the preceding Claims, wherein the ceramic body has a diameter and the belt member has a maximal thickness, which is at most about 10% of said diameter.

9. A composite armor unit according to any of the preceding Claims, wherein the belt member includes recesses disposed therein.

10. A composite armor unit according to any of the preceding Claims, wherein the belt member is in the form of a spiral.

11. A composite armor unit according to any of the preceding Claims, wherein the belt member has a height and thickness, which varies along said height.

12. A composite armor unit according to any of the preceding Claims, wherein the belt member is adapted to provide the cylindrical body portion with inward radial compression.

13. A composite armor unit according to any of the preceding Claims, wherein the belt member has a cup-shape and is adapted to receive said ceramic body therein.

14. Ballistic armor for providing ballistic protection from an impacting projectile threat, comprising a plurality of composite armor units as defined any of the preceding Claims.

15. Ballistic armor according to Claim 14, further including a backing layer adapted to trap fragments resulting from the impacting projectile threat.

16. Ballistic armor according to Claim 15, wherein said backing layer is made from one of the following: aluminum, Spectra®, Dyneema®, Kevlar™, Twaron™, High Density Poly-Ethylene, aramids, S_2 glass fibers, E glass fibers.

17. Ballistic armor according to any of the preceding Claims, further including a frontal spall cover adapted to trap fragments resulting from the impacting projectile threat.

18. Ballistic armor according to Claim 17, wherein said spall cover is made from one of the following: fiberglass, Kevlar™, themoset resin, thermoplatic resin.

19. Ballistic armor according to any of the preceding Claims, wherein said units are bound together by a binding material.

20. Ballistic armor according to Claim 19, wherein said binding material is thermoset plastic.

21. Ballistic armor according to Claim 19, wherein said binding material is a thermoplastic.

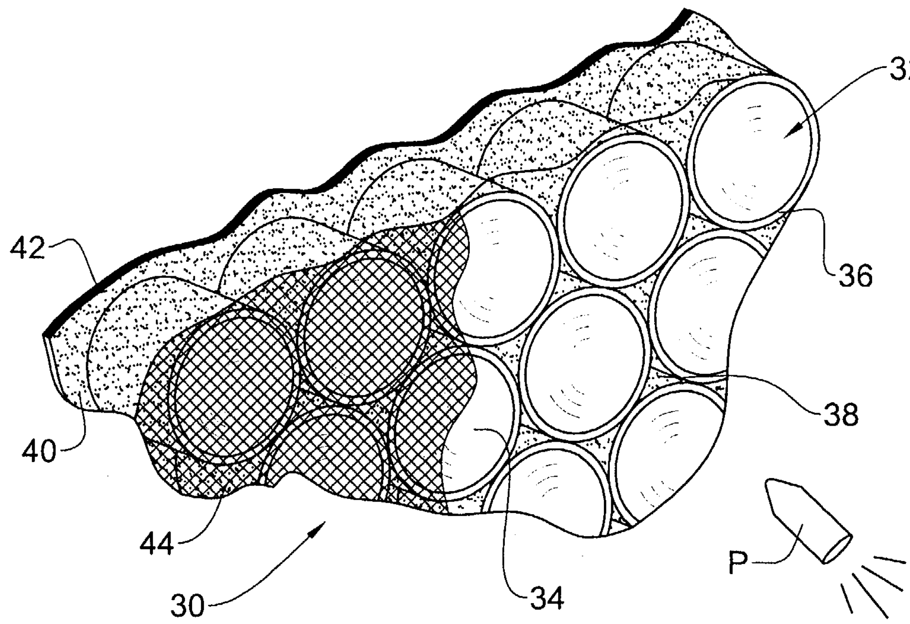

FIG. 1

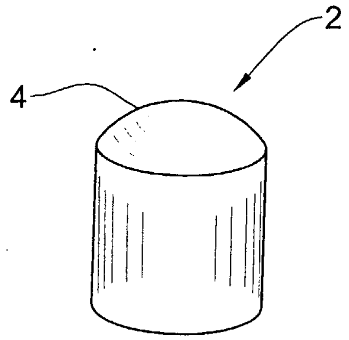

FIG. 2A (PRIOR ART)

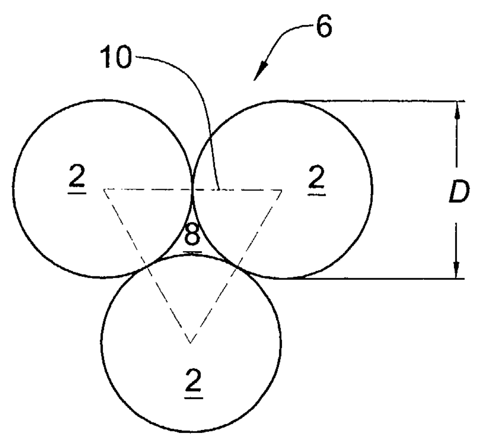

FIG. 2B (PRIOR ART)

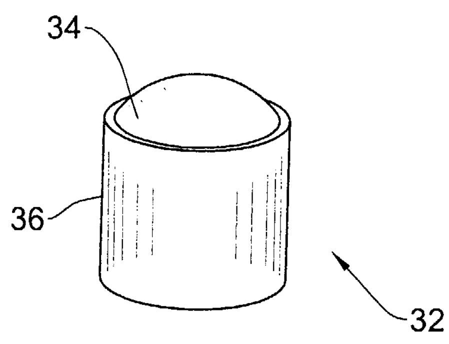

FIG. 3A

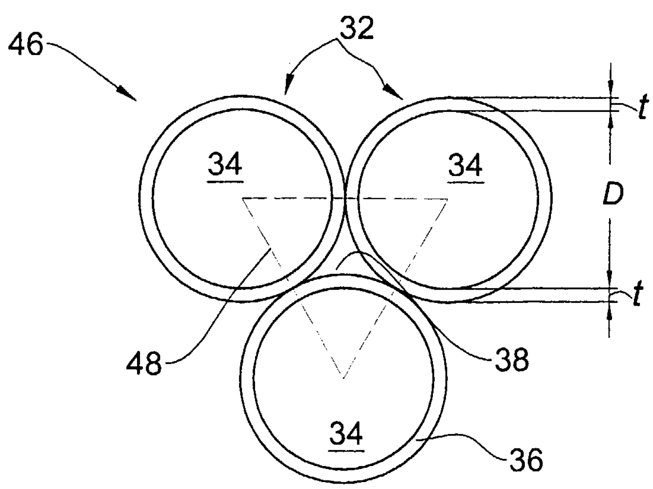

FIG. 3B

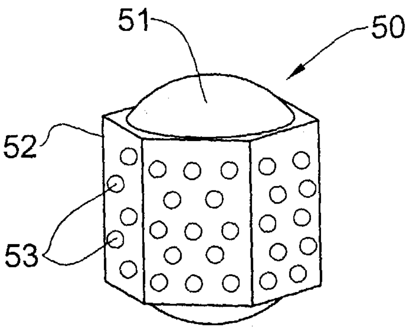

FIG. 4A

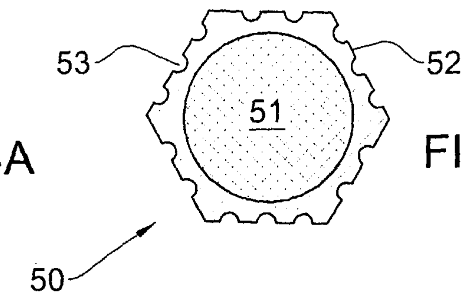

FIG. 4B

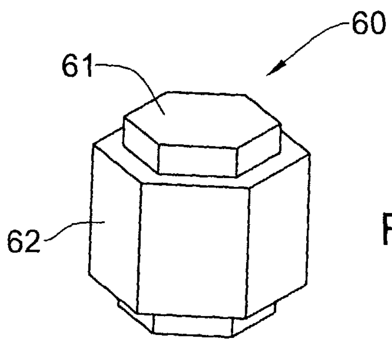

FIG. 4C

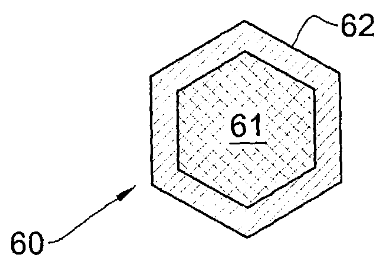

FIG. 4D

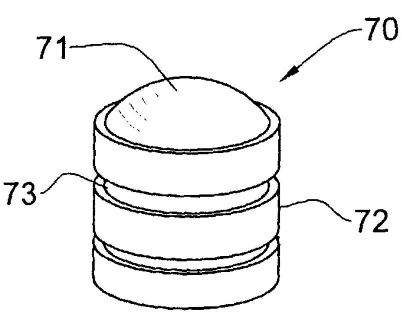

FIG. 4E

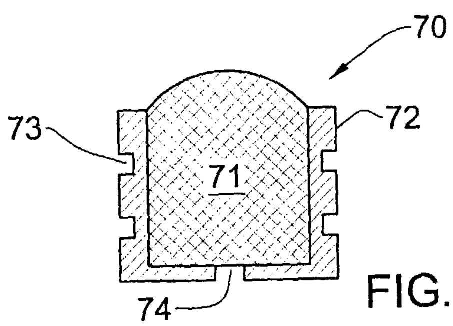

FIG. 4F

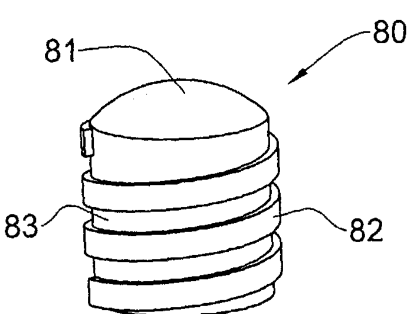

FIG. 4G

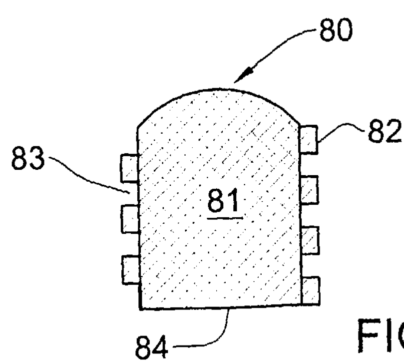

FIG. 4H

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EUROPEAN SEARCH REPORT

Application Number
EP 03 00 7391

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Place of search	Date of completion of the search	Examiner
MUNICH	18 August 2003	Ziegler, H-J

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